



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:  
25.08.1999 Bulletin 1999/34

(51) Int. Cl.<sup>6</sup>: G02B 6/38, G02B 6/40

(21) Application number: 99103428.1

(22) Date of filing: 23.02.1999

(84) Designated Contracting States:  
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU  
MC NL PT SE  
Designated Extension States:  
AL LT LV MK RO SI

(72) Inventor: Chong, Nyuon  
Kanata, Ontario K2M 1H8 (CA)

(74) Representative:  
Frei, Alexandra Sarah  
Frei Patentanwaltsbüro  
Postfach 768  
8029 Zürich (CH)

(30) Priority: 24.02.1998 US 75965

(71) Applicant: JDS FITEL INC.  
Nepean, Ontario K2G 5W8 (CA)

(54) **Tunable multiple fiber optical connector**

(57) The present invention relates to a connector (100) for receiving and connecting multiple optical fiber ends (22). In particular, the present invention relates to a tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends (22) to a second plurality of optical fiber ends comprising: a first connector housing (30A) comprising at least a first key element (36), the connector housing (30A) for retaining each of

the first plurality of optical fiber ends (22), a core (32) of each of the first plurality of optical fiber ends (22) oriented with respect to the same first key element (36) in a predetermined fashion in a plane perpendicular to the longitudinal axis of the fiber; and, a coupling mechanism for coupling the first connector housing (30A) to another connector housing (30B).

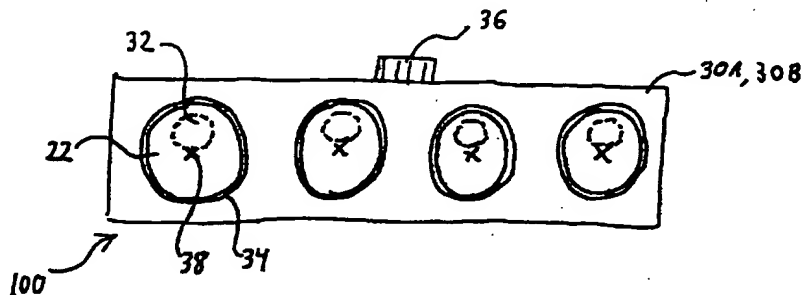


Fig. 5

## Description

[0001] A tuned multiple fiber optical connector and a method for tuning same is disclosed. A first connector housing retains each of a first plurality of optical fiber ends in a predetermined location. The first connector housing has a first key element. A core of each of the first plurality of optical fiber ends is oriented in a predetermined fashion with respect to the first key element. A second connector housing retains each of a second plurality of optical fiber ends in a predetermined location. The second connector housing comprises a second key element. A core of each of the second plurality of optical fiber ends is oriented in a predetermined fashion with respect to the second key element. The first and the second connector housings are coupled such that the key elements are disposed in a predetermined relation one to the other. Therefore, the core of each of the first plurality of optical fiber ends is substantially in alignment with the core of a corresponding optical fiber end of the second plurality of optical fiber ends.

[0002] The present invention relates to a connector for receiving and connecting multiple optical fiber ends. In particular, the present invention relates to a tunable multiple optical fiber connector for tuning the core position of each fiber in the connector to optimize coupling efficiency.

[0003] In fiber based optical systems, signals propagate within optical fibers. When optically coupling two components, a fiber is coupled at a first end to a first component and at a second end to a second component. Often in an optical system, a plurality of fibers is routed within the system. When a large number of fibers are used, designs often incorporate cables comprising a number of fibers and having a single connector at each end of the cable. The single multi-fiber connector is provided with bores for accepting optical fibers. Into each bore, a fiber is inserted and held in place. Unfortunately, the bores are not always precisely located and, in order to insert a fiber, the bores must be larger in diameter than the outside diameter of the fibers in order to accommodate the fibers.

[0004] Small irregularities in ferrule and fiber manufacture can result in significant signal loss, particularly in coupling single mode fibers. A standard ferrule has an internal diameter closely matching a fiber diameter. However, a ferrule having for example an internal diameter of 128  $\mu\text{m}$  provided with a fiber having a diameter of 127  $\mu\text{m}$  may be placed up to 0.5  $\mu\text{m}$  from the concentric axis, equaling a total possible eccentricity of the optical fiber of 1  $\mu\text{m}$ . In addition, the bore of the ferrule in manufacture may not be concentrically placed. Tuning is thus necessary to optimize the position of the fiber ends within a connector and thereby adjust the coupling efficiency. For example, a simple tuning apparatus allows for insertion of a connector in any of a plurality of orientations. Once inserted, the connector is fixed in its orientation and, therefore, the coupling efficiency

remains substantially constant and is improved when coupling is between two ends having similar orientations.

[0005] Unfortunately, when using cables comprising multiple fibers, each fiber coupling may result in significant loss. Tuning of fibers by moving the two connector ends does not result in each fiber pair being independently tuneable. The relative placement of the connector ends cannot be reoriented because the fiber connections would change. When different fibers within a cable have alignment errors as is commonly noted, it is near impossible to find two connectors that couple efficiently for all fiber pairs. For example, when correct alignment is sufficiently approximated by aligning the connectors in one of four orientations, there is a one in four chance of a good coupling. Through tuning of a single fiber connector, the coupling is easily altered to achieve a most efficient coupling from the four available orientations. When two fibers are incorporated into a cable, there are 16 possible orientations and since tuning is not available, only one in 16 connectors provides good coupling with an existing connector. When a cable having 32 fibers is used, the chance of finding two that mate with reasonable coupling efficiency is very small.

[0006] For more efficient installation of multi fiber or ribbon fibers the coupling of multiple fiber ends at a single multi-fiber-connector pair, heretofore, has not been satisfactory. United States patent No. 5,671,311 to Stillie et al. discloses a method of aligning a number of receiving ferrules within a less precise housing by providing aligning pins for locating the ferrule bores in the housing. Once the ferrules are positioned the fibers are then inserted. This is a rather imprecise method, which does not provide an opportunity to correct transmission problems once the fibers and light sources are in place. Also, since the fiber is inserted after the tuning is performed, slack between the ferrule and the fiber can be a significant problem.

[0007] Alternative multiple fiber connectors are disclosed in United States patent No. 5,430,819 to Sizer II et al. A first connector manufactured by AT&T under the trademark MACII, secures a plurality of exposed fiber ends between a pair of silicon wafers having a groove precision etched to locate each fiber end. A second connector in accordance with the invention of Sizer II et al. provides a pair of substrate plates having fiber-sized holes etched through the substrate for locating each fiber end. Both of these methods require absolutely precise manufacturing at considerable cost, since no tuning adjustment of individual fibers is possible.

[0008] Tuning of single optical fiber connectors is known. For example, it is known to provide a keying mechanism on an optical fiber connector to prevent rotation of the optical fiber cable once a desired coupling position has been determined, as described in United States patent No. 5,096,276 to Gerace et al. The key element may be an asymmetric shape or a pin or the like in a push-pull plug type connector.

[0009] Two fiber ends joined in a connector may each be supported in a ferrule or similar housing. Most commonly a cylindrical ferrule with a central bore substantially the diameter of the exposed fiber is used to support the fiber end within the connector. As recognized in United States patent No. 4738,508 to Palmquist, and also in United States patent No. 5390,269 to Palacek et al., tuning of the ferrules within the connector is also needed to achieve high performance connection with low insertion loss.

[0010] Palacek and Palmquist propose providing multiple rotatable orientations of a fiber and ferrule within the connector by placing the ferrule within a housing or collar having facets or knurls for mating with a receiving housing.

[0011] It is an object of the invention to provide a connector for receiving and connecting multiple optical fiber ends, in which each optical fiber core is oriented in a predetermined fashion with respect to a key element of a connector housing.

[0012] It is further an object of the invention to provide a connector for receiving and connecting multiple optical fiber ends, in which each optical fiber core can be tuned individually.

[0013] According to the present invention there is provided a tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends comprising:

a first connector housing comprising a first key element, the first connector housing for retaining each of the first plurality of optical fiber ends in a predetermined location, a core of each of the first plurality of optical fiber ends oriented in a predetermined fashion with respect to the first key element;

a second connector housing comprising a second key element, the second connector housing for retaining each of the second plurality of optical fiber ends in a predetermined location and a core of each of the second plurality of optical fiber ends oriented in a predetermined fashion with respect to the second key element; and,

a coupling mechanism for coupling the first and the second connector housings such that when the key elements are disposed in a predetermined relation one to the other, the core of each of the first plurality of optical fiber ends is substantially in alignment with the core of a corresponding optical fiber end of the second plurality of optical fiber ends.

[0014] In a preferred embodiment according to the invention there is further provided a tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends comprising:

a first plurality of optical fiber ends, wherein each optical fiber end is retained in a ferrule such that a core of the optical fiber end is oriented in a predetermined fashion with respect to a key element of the ferrule;

a second plurality of optical fiber ends, wherein each optical fiber end is retained in a ferrule such that a core of the optical fiber end is oriented in a predetermined fashion with respect to a key element of the ferrule;

a first connector housing comprising a first key element, the first connector housing for retaining each of the first plurality of optical fiber ends in a predetermined location such that the key elements of the ferrules are disposed in a predetermined relation to the first key element of the connector housing;

a second connector housing comprising a second key element, the second connector housing for retaining each of the second plurality of optical fiber ends in a predetermined location such that the key elements of the ferrules are disposed in a predetermined relation to the second key element of the connector housing; and,

a coupling mechanism for coupling the first and the second connector housings such that when the first and the second key elements are disposed in a predetermined relation one to the other, the core of each of the first plurality of optical fiber ends is substantially in alignment with the core of a corresponding optical fiber end of the second plurality of optical fiber ends.

[0015] According to the invention there is further provided a tunable multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends comprising:

a first plurality of optical fiber ends, wherein each optical fiber end is retained in a ferrule;

a second plurality of optical fiber ends, wherein each optical fiber end is retained in a ferrule;

a first connector housing comprising a first key element, the first connector housing for retaining each of the first plurality of optical fiber ends in a predetermined location such that each ferrule is retained in a bore within the first connector housing in one of a plurality of orientations and prevented from rotating by engaging means;

a second connector housing comprising a second key element, the second connector housing for retaining each of the second plurality of optical fiber

ends in a predetermined location such that each ferrule is retained in a bore within the second connector housing in one of a plurality of orientations and prevented from rotating by engaging means; and,

a coupling mechanism for coupling the first and the second connector housings such that when the key elements are disposed in a predetermined relation one to the other, the core of each of the first plurality of optical fiber ends is in a predetermined orientation with respect to the core of a corresponding optical fiber end of the second plurality of optical fiber ends.

[0016] According to the present invention there is provided a method for tuning a multiple fiber optic connector for connecting a plurality of optical fiber ends comprising the steps of:

iteratively,

determining a core orientation with respect to a reference point of each optical fiber end of the plurality of optical fiber ends;

when a core orientation is a predetermined orientation, affixing the optical fiber ends in a connector housing such that the core of each of the optical fiber ends is oriented in a predetermined fashion with respect to a key element of the connector housing; and,

when the core orientation is other than the predetermined orientation, altering the core orientation of at least one of the plurality of optical fiber ends.

[0017] In a preferred embodiment according to the present invention there is further provided a method for tuning a multiple fiber optic connector for connecting a plurality of optical fiber ends comprising the steps of:

determining a core orientation with respect to a reference point of each optical fiber end of the plurality of optical fiber ends;

when a core orientation is a predetermined orientation, affixing the optical fiber end in a ferrule such that the core of the optical fiber end is oriented in a predetermined fashion with respect to a key element of the ferrule;

when the core orientation is other than the predetermined orientation, altering the core orientation; and,

affixing the ferrules in a connector housing such that the key elements of the ferrules are disposed in

a predetermined relation to a key element of the connector housing.

[0018] In another preferred embodiment according to the present invention there is provided a method for tuning a multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends comprising the steps of:

affixing each of the first plurality and the second plurality of optical fiber ends in a ferrule;

mating a first connector housing with a second connector housing such that key elements are disposed in a predetermined relation one to the other indicating mating of the two connector housings in one and only one orientation;

placing each of the first plurality of optical fiber ends and the corresponding fiber of the second plurality of optical fiber ends into a first and second connector housing; respectively, such that cores of the first plurality of optical fiber ends and the corresponding core of the second plurality of optical fiber ends have a first orientation relative to each other;

simultaneously launching light through each of the first and second plurality of optical fibers;

adjusting the relative orientation of the cores of each fiber pair until a preferred coupling is obtained; and,

when a preferred coupling is obtained securing the orientation of the fiber cores with respect to the key elements by affixing the ferrules within the connector housings.

[0019] Exemplary embodiments of the invention will now be described in conjunction with the drawings, in which:

Figure 1A is a transverse sectional view of a prior art, single fiber connector prior to tuning;

Figure 1B is a transverse sectional view of the connector of Figure 1A subsequent to tuning;

Figure 2A is a transverse sectional view of a further prior art single fiber connector prior to tuning;

Figure 2B is a transverse sectional view of the connector of Figure 2A subsequent to tuning;

Figure 3 is an isometric view of a prior art MACII multiple optical fiber connector;

Figure 4 is an isometric view of a further prior art

multiple optical fiber connector;

Figure 5 is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention;

5

Figure 5A is an isometric view of the connector of Figure 5 comprising a color code as a key element;

Figure 5B is an isometric view of the connector of Figure 5 comprising a pin and a hole as a key element;

10

Figure 5C is an isometric view of the connector of Figure 5 comprising an asymmetric housing as a key element;

15

Figure 6A is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention indicating a fiber core orientation;

20

Figure 6B is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention indicating a fiber core orientation;

25

Figure 6C is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention indicating a fiber core orientation;

Figure 6D is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention indicating a fiber core orientation;

30

Figure 7A is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention wherein each optical fiber is retained in a separate bore;

35

Figure 7B is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention wherein all optical fibers are retained in one bore;

40

Figure 7C is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention wherein a housing comprises several bores, each bore retaining several optical fibers;

45

Figure 8A illustrates a tuned multiple optical connector in accordance with the present invention comprising male and female connector housings;

50

Figure 8B illustrates a tuned multiple optical connector in accordance with the present invention comprising two connector housings having a same shape mated together by a third intermediate housing;

55

Figure 8C illustrates a tuned multiple optical connector in accordance with the present invention comprising two connector housings having a same shape mated together;

Figure 8D illustrates a tuned multiple optical connector in accordance with the present invention comprising a first connector housing mated with two connector housings;

Figure 9A is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention, wherein optical fiber ends are supported by a ferrule and the ferrule has a flattened face for engaging with a side wall of a bore;

Figure 9B is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention, wherein optical fiber ends are supported by a ferrule and the ferrule has grooves for engaging with a pin mounted within a bore;

Figure 9C is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention, wherein optical fiber ends are supported by a ferrule and the ferrule has an octagonal collar for engaging with matching surfaces a bore;

Figure 9D is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention, wherein optical fiber ends are supported by a ferrule and the ferrule retains a plurality of optical fiber ends; and,

Figure 9E is a transverse sectional view of a tuned multiple optical connector in accordance with the present invention, wherein optical fiber ends are supported by a ferrule and a plurality of ferrules are retained in a single bore.

[0020] Figures 1A and 1B show an optical fiber end 22 within a prior art single tunable connector. The ferrule 8 supporting the fiber end 22 is surrounded by an octagonal collar 20 having outer faces 21. The connector includes a positioning channel 3 for engaging the faces 21 of the ferrule collar 20. The center of the ferrule 8 is marked 23. It can be seen in Figure 1A that the fiber end 22 is positioned eccentrically. The eight faces of the collar 20 provide eight rotational positions for placing the ferrule within the connector. A position is chosen for most efficiently coupling the fiber end to a connecting fiber end disposed within an associated mating connector element.

[0021] Figures 2A and 2B show an alternative embodiment of the single prior art connector. The outer collar 10 has twelve ridges and depressions about the ferrule 8. As a result twelve positions within the connector are

possible, allowing greater flexibility to the fiber positioning.

[0022] In modern communication networks a large amount of data is transferred via fiber optic cables. Fiber optic cables usually comprise a large number of individual optical fibers arranged, for example, in a ribbon like structure. Using a single connector for each fiber in order to connect two fiber optic cables is not a practical solution. The cable has to be split into the individual fibers a sufficient distance from the end so as to be able to connect each fiber pair individually. Further, substantial space is required for the large amount of connectors. This creates a large amount of fibers that are no longer aligned, crossing each other in different orientations. In such a confusing situation it is very likely that the wrong fibers are connected to each other. Also, maintenance and reliability are reduced because of the tangle of fibers that results. Therefore, it is preferable to connect the ends of two fiber optic cables with a single coupling.

[0023] Figures 3 and 4 illustrate prior art multiple connectors in which exposed fiber ends 101 and 201 are aligned in precisely machined locating plates. In both embodiments provision is made to adjust horizontal or vertical positioning of all of the fiber ends together to couple with an aligned additional set of fiber ends. No tuning of individual fibers is possible. Consequently, manufacturing irregularities such as variability in fiber diameter, eccentricity of the fiber core or variability in the machining of the plate cannot be compensated resulting in significant signal loss with each fiber coupling.

[0024] Figure 5 illustrates a transverse section through a multiple optical connector 100 in accordance with the present invention. The multiple optical connector 100 comprises a first housing 30A and a second housing 30B. Each housing 30A, 30B comprises a plurality of bores 34 for retaining the first and the second plurality of optical fiber ends 22, respectively. Each of a plurality of optical fiber ends 22 is retained in a bore 34 within the connector housings 30A, 30B such that an optical fiber core 32 is in a plane perpendicular to the longitudinal axis of the fiber above the center 38 of the bore 34 retaining the optical fiber end 22. In such an arrangement, each fiber core 32 is oriented with respect to a key element 36. The key elements 36 of the connector housings 30A, 30B are mating key elements for substantially limiting the coupling of the two connector housings 30A, 30B to a single orientation. When the connector housings 30A, 30B are coupled the key elements 36 are disposed in a predetermined relation one to the other. The core 32 of each optical fiber end 22 retained in the first connector housing 30A is then substantially in alignment with the core 32 of a corresponding optical fiber end 22 retained in the second connector housing 30B. Key elements 36 are for example as illustrated in figures 5B to 5C: a pin 70 to fit in a hole 71 or asymmetric connector housings 72A, 72B. Alternatively as shown in Fig. 5A, the key element is other than a

mating element, for example a colored mark 68.

[0025] Such a connector is manufactured by iteratively determining the core orientation of each optical fiber end 22 with respect to a reference point. When the core orientation is substantially the predetermined core orientation the optical fiber end 22 is affixed in the connector housing 30 such that the core 32 is oriented in a predetermined fashion with respect to the key element 36 of the connector housing 30. For example, the optical fiber ends 22 are affixed in the connector housing 30 using an adhesive such as epoxy. When the core orientation is other than the predetermined orientation, the core orientation is altered.

[0026] Provision of fiber optic cables with tuned and standardised multiple optical connectors, for example the fiber cores of all connectors are oriented in a same fashion as illustrated in Fig. 5, allows a user to connect fiber optic cables easily without a significant signal loss.

[0027] Figures 6A to 6D illustrate numerous possibilities to arrange the core orientation of the optical fiber ends 22 according to the present invention. The illustration in figure 6A shows the cores 32 of the optical fiber ends 22 having different orientations -up, right and down-. Such an arrangement of the fiber cores necessitates two different connector housings 30A, 30B for coupling, one being a mirror image of the other. In the arrangement shown in figure 6B the cores 32 of all optical fiber ends 22 point to one direction. Two connector housings 30A, 30B having such an arrangement are mated by turning one connector housing upside down. Figure 6C shows the fiber cores 32 retained in the left half of the connector housings 30A, 30B pointing to the left whereas the fiber cores 32 retained in the right half of the connector housings 30A, 30B are pointing to the right. Two such connector housings 30A, 30B are coupled either upside pointing to upside or one connector housing turned upside down relative to the other. The arrangements shown in figures 5 and 6A to 6C are useful for different embodiments of ribbon connectors. Figure 6D shows an arrangement of optical fibers 22 in a circular fashion, their cores 32 pointing from the center 33 of the circle outward. Such a connector allows coupling of two connector housings 31A, 31B in as many positions as the number of optical fibers 22 retained in the connector housings 31A, 31B by turning one housing about its center 33. Of course, when a single connector orientation is desired, a key for substantially limiting connector coupling orientation is included within the connector.

[0028] Figures 7A to 7C illustrate various arrangements of optical fiber ends 22 retained in a connector housing 30 according to the present invention. In figure 7A each of the optical fiber ends 22 is retained separately in a bore 34. This embodiment is advantageous for manufacturing because each fiber end 22 is oriented and affixed separately. In the embodiment shown in figure 7B all optical fiber ends 22 are retained in one bore 34. This arrangement of optical fibers requires the

smallest amount of space but is difficult to manufacture because all fibers ends 22 are affixed at a same time. Figure 7C shows an arrangement of the optical fiber ends 22 wherein the connector housing 30 comprises several bores 34 with each bore 34 retaining several fiber ends 22. Affixing the fibers is eased in this embodiment due to a reduced number of fibers retained in a single bore 34.

[0029] Figures 8A to 8D illustrate different embodiments of a multiple fiber optic cable and connector assembly. Two push-pull connector housings 30A, 30B join fiber ends from a first optical cable 40 and a second optical cable 42. The individual optical fibers are separated and stripped to expose the fiber ends 22 for placement in the connector housings 30A, 30B. A sufficient length of fiber is exposed to permit rotation of the fiber end through 180 degrees. Of course, a jacketed fiber is also rotatable and is considered exposed as that term is used herein. The loose fibers are provided with strain relief support elements and a covering (not shown). In the embodiment shown in figure 8A, two connector housings 30A, 30B of different shape to form a male and a female part are mated to couple the ends of the two fiber optic cables 40 and 42. Figure 8B shows two connector housings 30 of a same shape mated by a third intermediate housing 30C. This embodiment allows the use of fiber optic cables having a same connector housing 30 on both ends and therefore provides more flexibility during an installation of a network. These advantages are also provided by the connector housings shown in figure 8C where both connector housings 30 have a same shape, and do not need a third intermediate housing for mating the two connector housings 30. Figure 8D illustrates a multiple optical connector assembly 200 wherein one connector housing 30 is mated with two connector housings 50 and 52 to split one fiber optic cable 40 retaining a plurality of fibers into two fiber optic cables 42 and 44 each retaining fewer fibers. This is very useful for network applications where many parallel optical fibers are needed, for example, at a central station leading to different locations. Of course, such a connector assembly is useful for splitting a fiber optic cable into any number of fiber optic cables.

[0030] Figure 9A illustrates a transverse section through another embodiment of a multiple connector in accordance with the present invention. Each optical fiber end 22 is supported by a ferrule 5, and the ferrules 5 are positioned in individual bores 34 within the connector housing 30, wherein each bore 34 has cross section in the form of a quadratic cross section. A cooperative engagement between the ferrule 5 and the bore 34 is provided. As shown in Figure 9A the ferrule has a flattened face 6 for engaging one of the sidewalls 19 of the bore 34. A close fit prevents the ferrule 5 from rotating in position. It is evident to those of skill in the art that the term close fit relates to reasonable tolerances and not necessarily to a tight fit. Tolerances are selected based on design requirements and, as such, will vary.

As shown, the ferrule 5 may be positioned with the engaging face 6 against any one of the four sidewalls 19. In another embodiment shown in figure 9B the ferrule 5 comprises etched grooves 62 in a circumferential arrangement. Engaging one of the grooves 62 with a pin 60 in the connector housing bore 34 prevents the ferrule 5 from rotating in position. Figure 9C shows another aligned connector assembly in transverse section. Each of the ferrules 5 has an octagonal surrounding collar 64 to engage matching angular surfaces 66 of the connector housing bores 34. Optionally, a plurality of optical fibers 22 are retained in one ferrule 5 as illustrated in figure 9D. Further optionally, a plurality of ferrules 5 is retained in one connector housing bore 34 as shown in figure 9E, wherein the ferrules 5 have, for example, a hexagonal cross section.

[0031] A connector housing wherein optical fiber ends are supported by a ferrule 5 is manufactured by iteratively determining the core orientation of each optical fiber end 22 with respect to a reference point of the ferrule 5. When the core orientation is the predetermined core orientation the optical fiber end is affixed in the ferrule 5 such that the core of each of the optical fiber ends is oriented in a predetermined fashion with respect to an indicator element of the ferrule 5. Indicator elements are, for example, a groove 62 or a flattened face 6. When the core orientation is other than the predetermined orientation, the core orientation of the optical fiber end 22 is altered. After the optical fiber 22 has been affixed in the ferrule 5, the ferrule 5 is inserted into a bore 34 of the connector housing 30 such that the key element of the ferrule 5 is disposed in a predetermined relation to a key element 36 of the connector housing 30. After insertion the ferrule 5 is affixed in the bore 34.

[0032] In another embodiment a multiple fiber optic connector for connecting a first plurality of optical fiber ends 22 to a second plurality of optical fiber ends 22 is tuned by mating a first connector housing 30A with a second connector housing 30B such that key elements 36 are disposed in a predetermined relation one to the other indicating mating of the two connector housings 30A, 30B in one and only one orientation. Then, each of the first plurality of optical fiber ends 22 and the corresponding fiber end of the second plurality of optical fiber ends 22 are placed into a first connector housing 30A and second connector housing 30B, respectively, such that cores of the first plurality of optical fiber ends 22 and the corresponding core of the second plurality of optical fiber ends 22 have a first orientation relative to each other. Simultaneously light is launched through each of the first and second plurality of optical fibers. The relative orientation of the cores 32 of each fiber pair is adjusted until a preferred coupling is obtained. When a preferred coupling is obtained the orientation of the fiber cores 32 with respect to the key elements 36 is secured by affixing the fibers ends 22 within the connector housings 30A, 30B.

[0033] Preferably, each optical fiber end is retained in

a ferrule 5 for support. It is important to provide nearly concentric rotation of the ferrule within the bore so that eccentricities in the position of the fiber core are adjusted without introducing additional change in position from the engaging between the ferrule and the bore. Clearly, some error will occur in manufacture.

[0034] In a further embodiment, a connector according to the invention is formed such that individual fiber alignments within the multiple fiber connector are purposely skewed or offset by individually adjusting particular connectors so as to provide a preferred amount of attenuation between predetermined pairs. Hence, the individual adjustability provides enhanced coupling between individual pairs, or alternatively reduced coupling between particular pairs. Such a connector is highly advantageous in communication networks to equalise the signal intensity in parallel optical fibers after an imbalanced switching device or filtering process.

[0035] The invention disclosed herein provides a tuned multiple optical connector by aligning cores of a plurality of optical fiber ends with respect to a key element of a connector housing retaining said optical fiber ends. Standardisation of the orientation of the cores of the optical fiber ends provides multiple optical connectors for connecting fiber optic cables without significant signal loss or alternatively, with predetermined signal loss. It further allows connection of any fiber optic cables comprising such connectors without adjustment of core orientation during installation.

[0036] A tunable multiple optical connector allowing tuning of individual optical fiber alignments within the multiple optical connector is disclosed. The connector provides a method of individually tuning optical fiber alignment within such a connector for correcting manufacturing irregularities and other imprecision relating to connector construction and use. Of course, numerous other embodiments may be envisaged, without departing from the spirit and scope of the invention.

#### Claims

1. A tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends comprising:
  - a first connector housing comprising at least a first key element, the connector housing for retaining each of the first plurality of optical fiber ends, a core of each of the first plurality of optical fiber ends oriented with respect to the same first key element in a predetermined fashion in a plane perpendicular to the longitudinal axis of the fiber; and,
  - a coupling mechanism for coupling the first connector housing to another connector housing.
2. A tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends as defined in claim 1, comprising:
  - a second connector housing comprising a second key element, the second connector housing for retaining each of the second plurality of optical fiber ends in a predetermined location and a core of each of the second plurality of optical fiber ends oriented in a plane perpendicular to the longitudinal axis of the fiber in a predetermined fashion with respect to the second key element; and,
  - a coupling mechanism for coupling the second connector housing to the first connector housing such that when the second key element and the first key element are disposed in a predetermined relation one to the other; the core of each of the second plurality of optical fiber ends is approximately in alignment with the core of a corresponding optical fiber end of the first plurality of optical fiber ends.
3. A tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends as defined in claim 1, wherein the first key element is a mating key element for substantially limiting coupling of the first connector housing and another second connector housing to a single orientation.
4. A tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends as defined in claim 1, wherein the first connector housing comprises a plurality of bores, each bore for retaining one optical fiber end.
5. A tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends as defined in claim 1, wherein the first connector housing comprises a bore for retaining a plurality of optical fiber ends.
6. A tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends comprising:
  - a first plurality of optical fiber ends, wherein each optical fiber end is retained in a ferrule having at least an indicator element such that a core of the optical fiber end is oriented in a plane perpendicular to the longitudinal axis of the fiber, the orientation in a predetermined fashion with respect to an indicator element of the ferrule;



a first connector housing comprising a first key element, the first connector housing for retaining each of the first plurality of optical fiber ends in a predetermined location such that the indicator elements of the ferrules are disposed in a predetermined relation to the first key element of the first connector housing; and,

a coupling mechanism for coupling the first connector housing to another connector housing.

7. A tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends as defined in claim 6, comprising:

a second plurality of optical fiber ends, wherein each optical fiber end is retained in a ferrule such that a core of the optical fiber end is oriented in a plane perpendicular to the longitudinal axis of the fiber, the orientation in a predetermined fashion with respect to an indicator element of the ferrule;

a second connector housing comprising a second key element, the second connector housing for retaining each of the second plurality of optical fiber ends in a predetermined location such that the indicator elements of the ferrules are disposed in a predetermined relation to the second key element of the connector housing; and,

a coupling mechanism for coupling the second connector housing to the first connector housing such that when the second key element and a first key element of the first connector housing are disposed in a predetermined relation one to the other, the core of each of the second plurality of optical fiber ends is substantially in alignment with the core of a corresponding optical fiber end of the first plurality of optical fiber ends retained in the first connector housing.

8. A tuned multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends as defined in claim 6, wherein the ferrule retains a plurality of optical fiber ends.

9. A tunable multiple fiber optic connector for connecting a first plurality of optical fiber ends retained within a plurality of ferrules to a second plurality of optical fiber ends comprising:

a first connector housing comprising a first key

element, the first connector housing for retaining each of the plurality of ferrules in an opening within the first connector housing in one of a plurality of orientations in a plane perpendicular to the longitudinal axis of the opening and prevented from rotating by engaging means; and,

a coupling mechanism for coupling the first connector housing and another connector housing.

10. A tunable multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends as defined in claim 9 comprising:

a plurality of ferrules, each ferrule for retaining an optical fiber end having a core wherein the ferrules are physically keyed for insertion into the openings within the first connector housing in each of at least two different orientations.

11. A tunable multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends as defined in claim 10, comprising:

a first plurality of optical fiber ends, wherein each optical fiber end is retained in a ferrule from the plurality of ferrules;

a second plurality of optical fiber ends, wherein each optical fiber end is retained in a ferrule;

a second connector housing comprising a second key element, the second connector housing for retaining each of the second plurality of optical fiber ends in a predetermined location such that each ferrule is retained in an opening within the second connector housing in one of a plurality of orientations in a plane perpendicular to the longitudinal axis of the opening and prevented from rotating by engaging means; and,

a coupling mechanism for coupling the second connector housing and the first connector housing such that when the key elements are disposed in a predetermined relation one to the other, the core of each of the second plurality of optical fiber ends is in a predetermined orientation in a plane perpendicular to the longitudinal axis of the bore with respect to the core of a corresponding optical fiber end of the first plurality of optical fiber ends.

12. A method for tuning a multiple fiber optic connector

for connecting a plurality of optical fiber ends comprising the steps of:

iteratively,

determining a core orientation in a plane perpendicular to the longitudinal axis of the core within the fiber, the orientation with respect to a reference point of each optical fiber end of the plurality of optical fiber ends;

when a core orientation is a predetermined orientation in the plane, affixing the optical fiber ends in a connector housing such that the core of each of the optical fiber ends is oriented in the plane in a predetermined fashion with respect to a key element of the connector housing; and,

when the core orientation is other than the predetermined orientation, altering the core orientation of at least one of the plurality of optical fiber ends.

13. A method for tuning a multiple fiber optic connector for connecting a plurality of optical fiber ends comprising the steps of:

determining a core orientation in a plane perpendicular to the longitudinal axis of the core within the fiber, the orientation with respect to a reference point of each optical fiber end of the plurality of optical fiber ends;

when a core orientation is a predetermined orientation, affixing the optical fiber end in a ferrule such that the core of the optical fiber end is oriented in a plane perpendicular to the longitudinal axis of the fiber, the orientation in a predetermined fashion with respect to an indicator element of the ferrule;

when the core orientation is other than the predetermined orientation, altering the core orientation; and,

affixing the ferrules in a connector housing such that the indicator elements of the ferrules are disposed in a predetermined relation to a key element of the connector housing.

14. A method for tuning a multiple fiber optic connector for connecting a first plurality of optical fiber ends to a second plurality of optical fiber ends comprising the steps of:

affixing each of the first plurality and the second plurality of optical fiber ends in a ferrule;

mating a first connector housing with a second connector housing such that key elements are disposed in a predetermined relation one to the other indicating mating of the two connector housings in one and only one orientation;

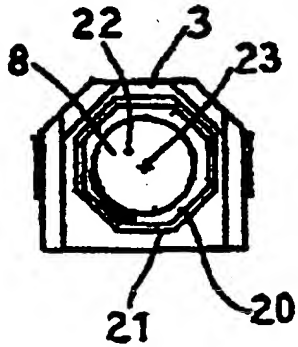
placing each of the first plurality of optical fiber ends and the corresponding fiber of the second plurality of optical fiber ends into a first and second connector housing, respectively, such that cores of the first plurality of optical fiber ends and the corresponding core of the second plurality of optical fiber ends have a first orientation relative to each other in a plane perpendicular to the longitudinal axis of the core within the fiber;

simultaneously launching light through each of the first and second plurality of optical fibers;

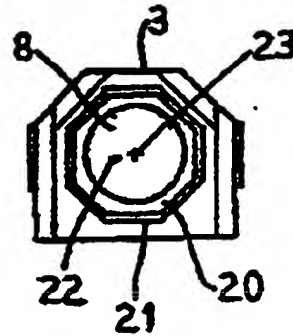
adjusting the relative orientation of the cores of each fiber pair until a preferred coupling is obtained; and,

when a preferred coupling is obtained securing the orientation of the fiber cores with respect to the key elements by affixing the ferrules within the connector housings.

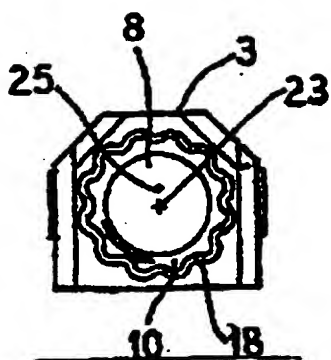
**Fig. 1A**  
**(PRIOR ART)**



**Fig. 1B**  
**(PRIOR ART)**

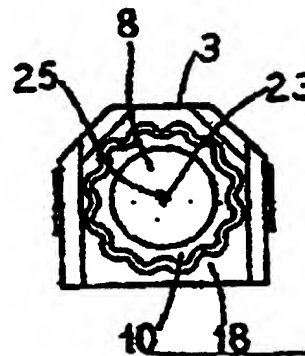


**Fig. 2A**



**PRIOR ART**

**Fig. 2B**



**PRIOR ART**

Fig. 3

PRIOR ART

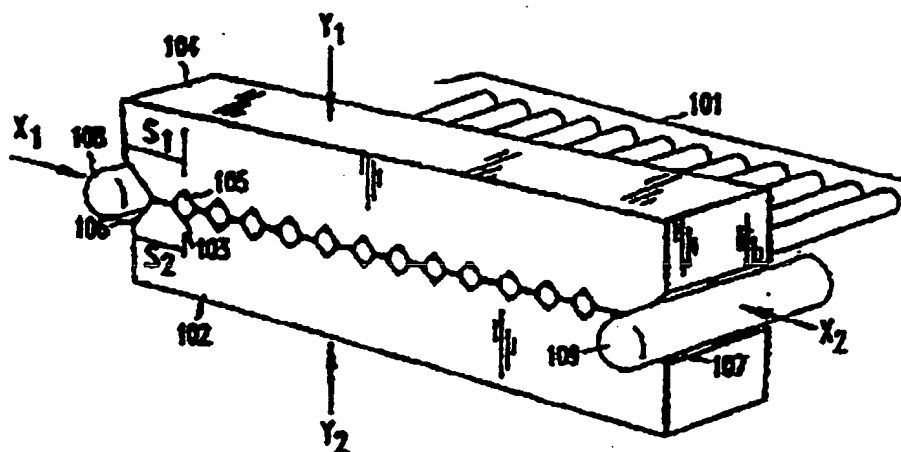
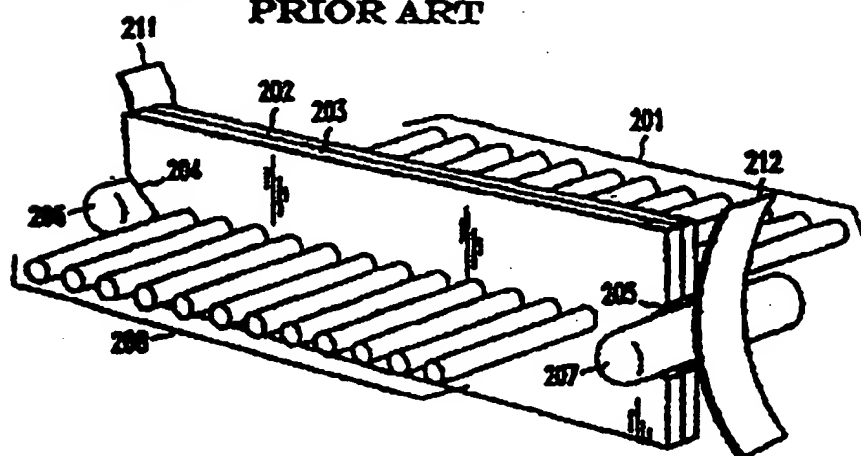


Fig. 4

PRIOR ART



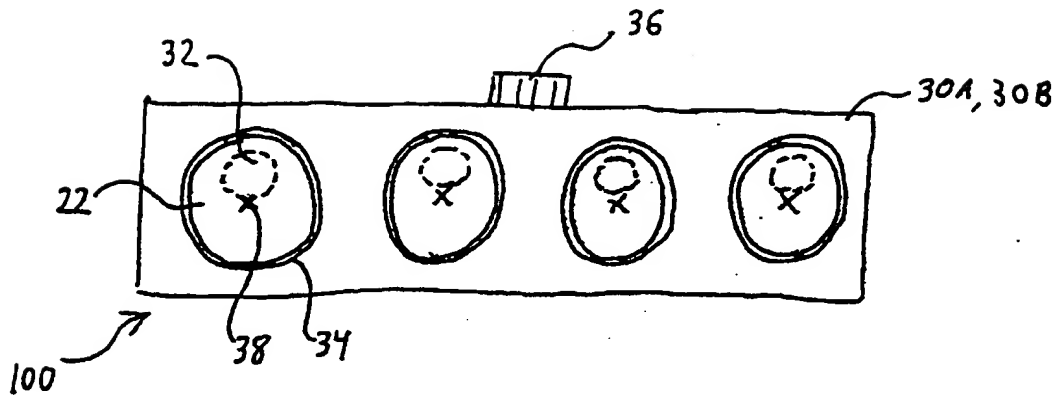


Fig. 5

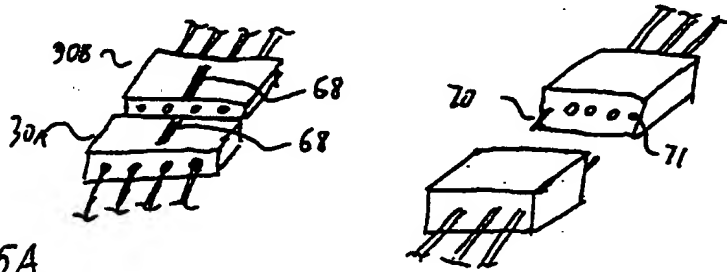


Fig. 5A

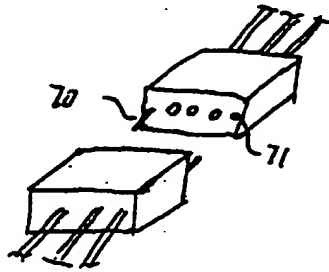


Fig. 5B



Fig. 5C

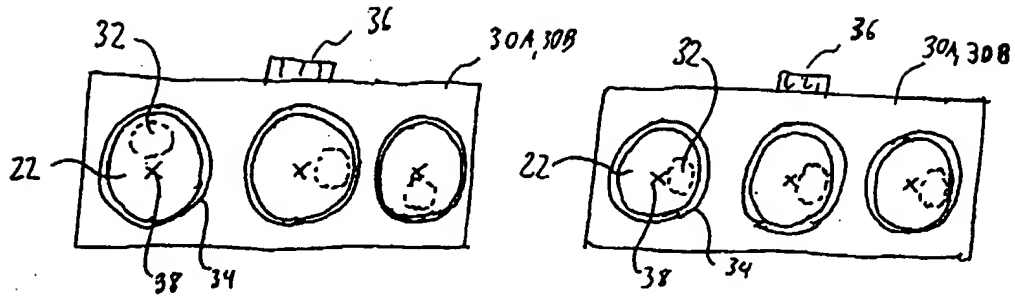


Fig 6A

Fig 6B

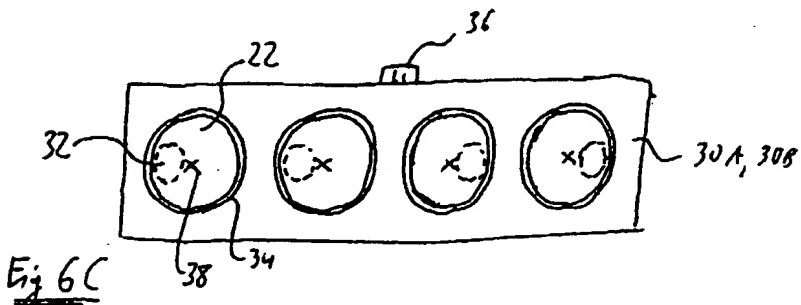


Fig 6C

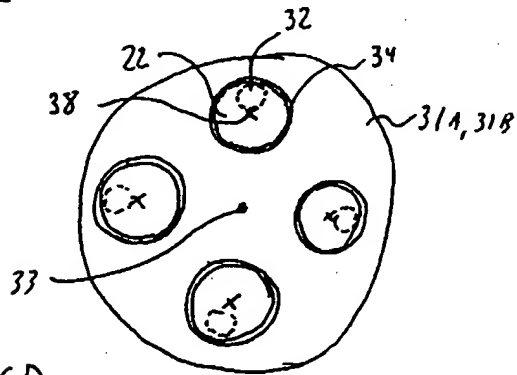


Fig 6D

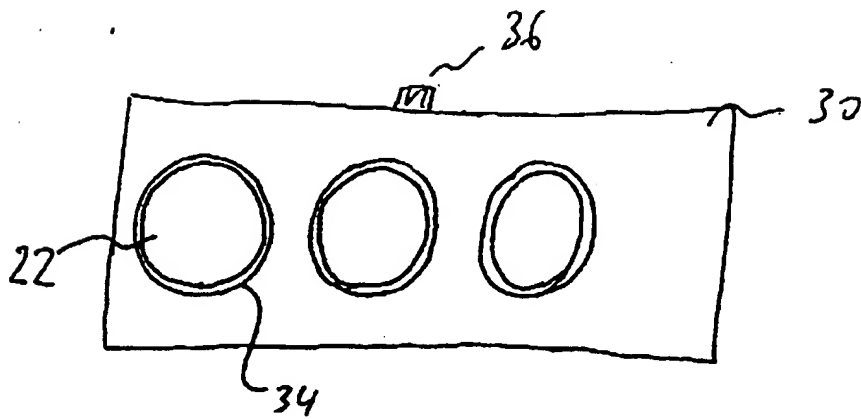


Fig 7A

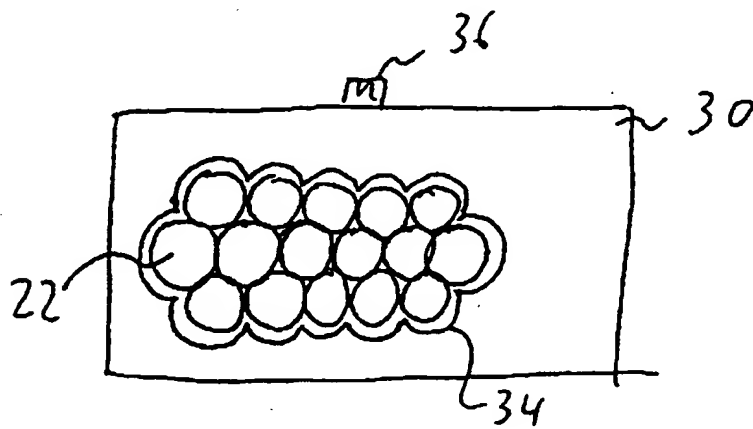


Fig 7B

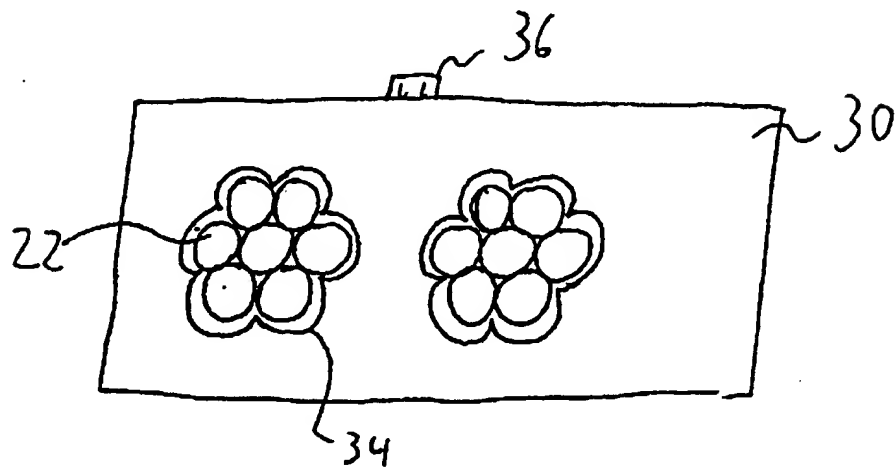


Fig 7C

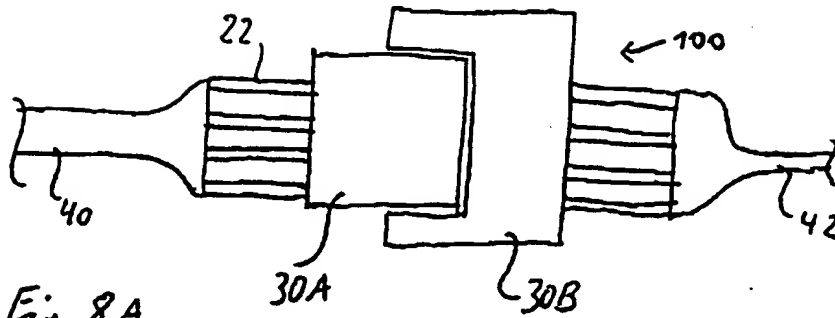


Fig 8A

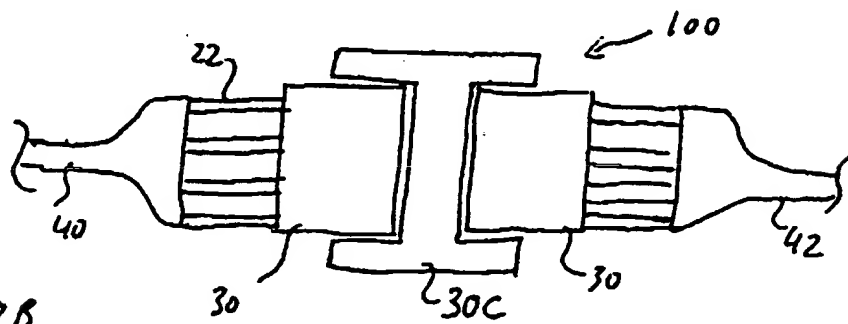


Fig 8B

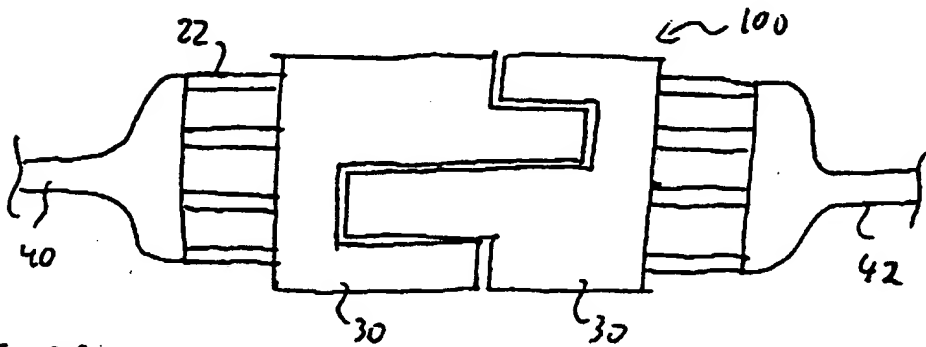


Fig 8C

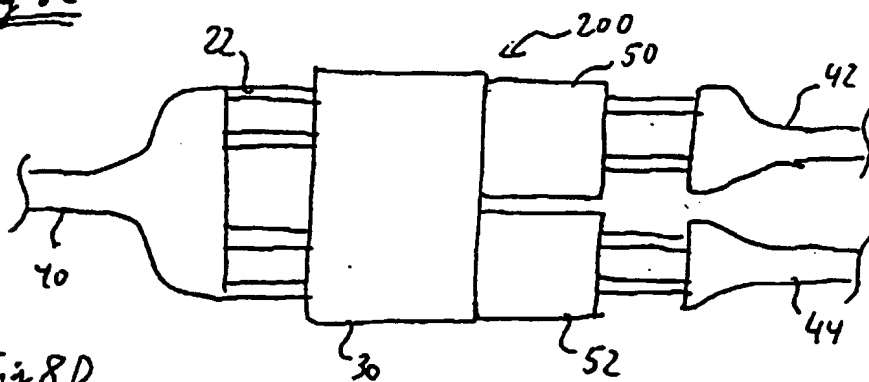


Fig 8D



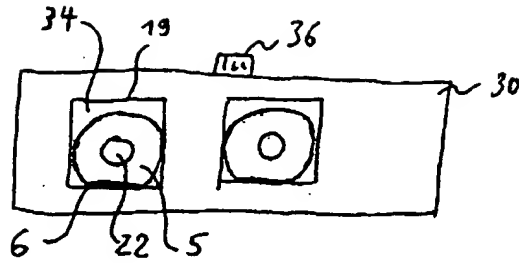


Fig 9A

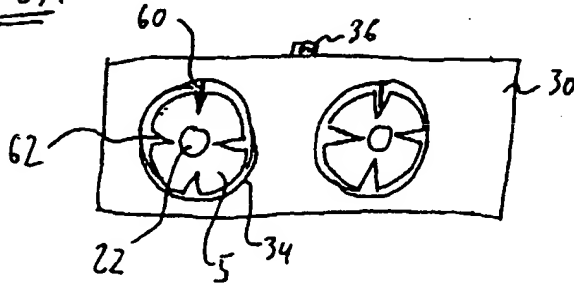


Fig 9B

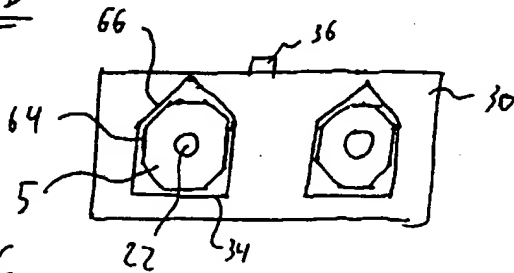


Fig 9C

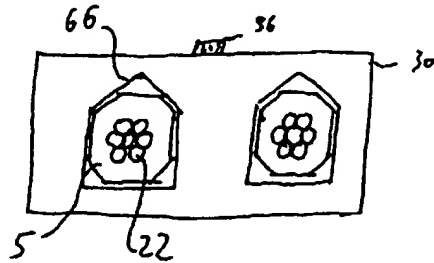


Fig 9D

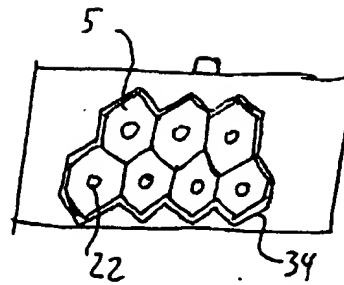


Fig 9E



European Patent  
Office

## EUROPEAN SEARCH REPORT

Application Number

DOCUMENTS CONSIDERED TO BE RELEVANT			EP 99103428.1
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 6)
A, D	US 4738508 A (PALMQUIST, J.M.) 19 April 1988, column 4, line 44 - column 9, line 68.	1-3, 6 7, 9-14	G 02 B 6/38 G 02 B 6/40
A	EP 0819960 A2 (SEIKO INSTRUMENTS, INC.) 21 January 1998, abstract, column 9, line 31 - column 12, line 33, column 18, line 46 - column 20, line 13, column 22, line 10 - column 26, line 19, fig. 1, 10, 11.	1, 3, 4 6, 7, 9 12-14	
A	EP 0640855 A1 (FUJIKURA LTD.) 01 March 1995, column 4, line 37 - column 7, line 32.	1, 6, 9 12-14	
A, D	US 5390269 A (PALECEK et al.) 14 February 1995, fig. 1-7.	1, 6, 9 12-14	G 02 B
A	US 5093881 A (BORTOLIN et al.) 03 March 1992, fig. 1-8.	1-4, 6 8, 9, 14	
The present search report has been drawn up for all claims			
Place of search <b>VIENNA</b>		Date of completion of the search <b>31-05-1999</b>	Examiner <b>GRONAU</b>
<p><b>CATEGORY OF CITED DOCUMENTS</b></p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons &amp; : member of the same patent family, corresponding document</p>			

EPO FORM 1503 02.82 (1/94d1)

**ANNEX TO THE EUROPEAN SEARCH REPORT**  
**ON EUROPEAN PATENT APPLICATION NO. EP 99103428.1**

This annex lists the patent family members relating to the patent documents cited in the above-mentioned search report.  
 The members are as contained in the EPIIOS INPADOC file on 9. 6.1999.  
 The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US A 4738508	19-04-1988	CA A1 1252662	18-04-1989
		CN A 86104201	01-04-1987
		CN B 1019609	23-12-1992
		DE C0 3686672	15-10-1992
		DE T2 3686672	25-03-1993
		EP A1 205984	30-12-1986
		EP B1 205984	09-09-1992
		JP A2 62011807	20-01-1987
EP A2 819960	21-01-1998	JP A2 11002744	06-01-1999
		CN A 1175002	04-03-1998
		EP A3 819960	30-12-1998
EP A1 640855	01-03-1995	CA AA 2130862	27-02-1995
		CA C 2130862	21-10-1997
		DE C0 69408752	09-04-1998
		DE T2 69408752	02-07-1998
		EP B1 640855	04-03-1998
		JP A2 7191229	28-07-1995
		US A 5457765	10-10-1995
		JP A2 7191228	28-07-1995
		JP A2 7063942	10-03-1995
US A 5390269	14-02-1995	CA AA 2110321	24-06-1994
		DE A1 4343063	30-06-1994
		FR A1 2699689	24-06-1994
		FR B1 2699689	12-01-1996
		GB A0 9311802	26-01-1993
		GB A1 2273789	28-07-1994
		GB B2 2273789	19-06-1994
		JP A2 6222244	12-08-1994
US A 5093881	03-03-1992	AU A1 63254790	26-04-1991
		AU B2 632623	07-01-1993
		BR A 9005338	17-05-1991
		CA AA 2027732	18-04-1991
		CA C 2027732	07-01-1997
		EP A2 423581	24-04-1991
		EP A3 423581	17-07-1991
		IT A0 8922040	17-10-1989
		IT A 1237091	18-05-1993
		JP A2 3171018	24-07-1991
		MX B 172160	06-12-1993
		NZ A 235543	26-03-1993

For more details about this annex see Official Journal of the European Patent Office, No. 12/82.